

## **Appendix C**

### **SPECIFICATION FOR TURBINE OIL**

#### **GUIDANCE ON THE USE OF THIS SPECIFICATION**

The specification below is for zinc and chlorine-free petroleum-based turbine oils for use at hydroelectric power plants in generator and turbine bearings, Kaplan turbine hubs, and governor systems. For additional guidance, reference Chapter 11, Engineer Manual EM 1110-2-1424, Lubricants and Hydraulic Fluids for Civil Works Project

Compatibility between new oil and in-service oils must be evaluated and determined by lab testing. Only oils found to be compatible will be mixed with in-service oil or used as replacement oil. The compatibility testing is necessary because the new oils currently readily available on the market are formulated with different base oils than the in-service oils, and their additives may not be fully compatible with additives of the in-service oils. This specification shall be used for the procurement of all turbine oils, whether purchased for initial installation, filling rehabbed hydroelectric units, or for use as additional turbine oil at operating projects.

There are essentially two viscosity grades of turbine oil for hydro turbines, ISO 68 and ISO 100, their characteristics requirements are listed in TABLE 2. The following criteria should be used in choosing these oils for the powerhouse.

1. New powerhouses should use turbine oil of the viscosity that is outlined in the design specifications.
2. Powerhouses that use ISO 68 oil in their Kaplan turbine runner hubs and are experiencing a stick/slip problem with their blade operating mechanism should investigate a changeover to ISO 100 turbine oil.
3. Powerhouses using ISO 68 oil with no problem should continue to use that oil.

The method of shipment, type of containers, delivery dates, delivery point, delivery point of contact, and other required information should be included in appropriate sections of the contract specifications.

The turbine oil shall meet or exceed the chemical and physical requirements specified in TABLE 2. Additional characteristics or changes in listed values should not be included in the specifications without prior consultation with the technical proponent of the specification. The Corps' Districts/Projects may perform Quality Assurance (QA) tests on samples taken at the delivery point. The QA tests should include, as a minimum, the viscosity, acid number, elemental spectroscopy, and oxidation stability. Samples shall be taken from each bulk shipment and from not less than 10 percent of the drums taken at random from drum shipments. Such samples shall be not less than 4 L (1 gal), which may be stored in more than one sample container, and a portion of each sample shall be saved for later confirmation tests in the event that the results from the first tests indicate that the oil does not meet the specification requirements.

When soliciting for new contracts or orders using this specification for purchase of turbine oil that will be mixed with the in-service oil or as a replacement oil, the government should require all offerors to provide a 1-gallon sample of the proposed oil, which must meet the requirements of this specification in order to be eligible for award. The solicitation must include the following language - The Government may test this oil for compatibility with the in-service oil prior to awarding the Contract by sending a portion (1 qt) of new oil in an unmarked container, and a sample of in-service oil to a lab. The remaining

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quantity of new oil should be retained by the Government for possible further testing. Compatibility testing should be performed at no charge to the bidders.

The Districts/Project office can contact Hydroelectric Design Center (HDC) for information on sources of testing services.

## SPECIFICATION FOR TURBINE OIL

### TURBINE OIL

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#### 1. GENERAL

This specification covers zinc and chlorine-free rust and oxidation inhibited (R&O) mineral oils for use in hydraulic turbine and generator bearings, Kaplan turbine hubs, hydraulic-turbine governors, and other applications, where high-grade lubricating oil having anti-corrosion, anti-oxidation, and anti-foaming properties is required.

#### 2. REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

#### AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 92	(2002b) Flash and Fire Points by Cleveland Open Cup
ASTM D 97	(2004) Pour Point of Petroleum Oils
ASTM D 130	(2004) Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D 445	(2004e1) Kinematic Viscosity of Transparent and Opaque Liquids (and the Calibration of Dynamic Viscosity)
ASTM D 664	(2004e1) Acid Number of Petroleum Products by Potentiometric Titration
ASTM D 665	(2003) Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
ASTM D 892	(2003) Foaming Characteristics of Lubricating Oils

ASTM D 943	(2004a) Oxidation Characteristics of Inhibited Mineral Oils
ASTM D 1401	(2002) Water Separability of Petroleum Oils and Synthetic Fluids
ASTM D 2270	(2004) Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 Degrees C
ASTM D 2272	(2002) Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel Oxidation Test
ASTM D 3427	(2003) Air Release Properties of Petroleum Oils
ASTM D 4057	(2000) Manual Sampling of Petroleum and Petroleum Products
ASTM D 4177	(2000) Automatic Sampling of Petroleum and Petroleum Products)
ASTM D 6304	(2004ae1) Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fisher Titration

#### INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 4406	(1999) Coding the Level of Contamination by Solid Particles
ISO 11171	(1999) Calibration of Automatic Particle Counters for Liquids

### 3. SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. The following shall be submitted:

#### 3.1. DATA

Data of Chemical and Physical Characteristics of Turbine Lubricating Oil, G [, \_\_\_\_\_ ]

The Contractor shall furnish [ \_\_\_\_\_ ] copies of certified test data, which show that the oil meets or exceeds characteristics values specified in TABLE 2. The certified test data shall be submitted for approval 30 days before the oil delivery.

#### 3.2. SAMPLES

A gallon of proposed turbine oil, G [, \_\_\_\_\_ ]

The prospective bidder shall send one gallon of oil to the Government along with the bid. This oil shall be closely representative to the oil being offered in the bid. The Government plans to send a quart of this oil in an unmarked container to an independent laboratory for compatibility testing with the in-service oil. The compatibility testing will be performed at no charge to the prospective bidder. If the submitted oil sample is found to be incompatible with the in-service oil, this oil will not be further considered in the Contract awarding process.

#### 4. TURBINE OIL CHARACTERISTICS AND REQUIREMENTS

##### 4.1 GENERAL PROPERTIES

The turbine oil should be a blend of virgin petroleum-based stocks plus additives, free of zinc and chlorine, resulting in a high-grade turbine oil having anti-rust, anti-oxidation and anti-foaming properties suitable for use in hydraulic turbines, generator bearings, Kaplan turbine hubs and related applications.

##### 4.2 VISCOSITY

The oil viscosity should fall within the range as specified in TABLE 2.

##### 4.3 CHEMICAL AND PHYSICAL CHARACTERISTICS

The turbine oil shall conform to the requirements established in TABLE 2 when tested according to the standards indicated there.

##### 4.4 DEGRADATION

The physical and chemical properties of the oil shall not be degraded (changed from specified values in TABLE 2) by filtration through two-micron mechanical type filters, by centrifugal purification, or by vacuum type purifier, all of which have been designed for turbine oil.

##### 4.5 HOMOGENEITY

Additive agents shall remain uniformly distributed throughout the oil at all temperatures above the pour point and up to 120 °C (250 °F). When the oil is cooled below the pour point, it shall regain homogeneity while standing at temperatures of 5 °C (10 °F) above the pour point, and retain clear and bright appearance.

##### 4.6 COMPATIBILITY

Before the oil is being purchased for addition to existing (in-service) oil or as replacement oil, the Government will perform an independent compatibility testing of the two oils (new and in-service oil). The testing shall be performed in accordance with paragraph COMPATIBILITY TESTING and evaluated in accordance with paragraph APPEARANCE RATING PROCEDURE. If wish to conduct the test, potential suppliers shall contact the Contracting Officer to obtain a representative sample of the in-service oil required. The paragraphs COMPATIBILITY, COMPATIBILITY TESTING, and APPEARANCE RATING PROCEDURE are not applicable for new construction.

#### 5. TESTING

##### 5.1 COMPATIBILITY TESTING

The following testing procedure shall be used for evaluation of compatibility between new and in-service oils (for convenience, new oils are called “A” oils, and in-service oils are called “B” oils):

- a. Prepare separately 300 ml of each mixture of the following ratios: 90:10, 50:50, and 10:90 of the two oils (A and B) to be evaluated for compatibility. The two constituent oils (100:0, and 0:100) shall be tested concurrently.
- b. Stir each mixture vigorously in a laboratory glass mixer (minimum volume capacity of one quart) for 30 minutes, and immediately transfer to a glass beaker of suitable size for each mixture. Use a suitable rubber spatula, and squeegee the remaining oil into the glass beaker.
- c. Heat the beakers with the mixtures in the oven at 65 °C (150 °F) for 168 hours ( $\pm$  1 hour).
- d. Remove the beakers from the oven and allow to cool to room temperature.
- e. Observe the oil samples according to the procedure described in paragraph 5.2, Appearance Rating Procedure. If any of the oil mixtures tested display an incompatible result, conclude the test and report that the new oil is not acceptable for use. If the results are satisfactory, proceed to the next section.
- f. Cool the beakers with the oil mixtures to 0 °C (32 °F) and keep them at this temperature for 24 hours.
- g. Remove beakers from the cooler and bring to room temperature.
- h. Observe the oil samples according to the procedure described in paragraph 5.2. Appearance Rating. If any of the oil mixtures tested displays an incompatible result, the new shall be reported as incompatible, and as such, not acceptable for use.

## 5.2 APPEARANCE RATING PROCEDURE

Set up the appearance-rating test using a 150-Watt reflector flood lamp.

### a. SEDIMENT RATING

Hold the sample beaker vertically few inches above the flood lamp, without disturbing the sample, approximately ten inches in front of your eyes. View the sample beaker from the different directions, angles and distances from the light source bottom. Assign the observed sediment rating according to TABLE 1.

### b. FLUID RATING

View the sample beaker from the side, looking directly through the oil mixture. Assign a fluid rating according to TABLE 1. If the samples are too dark to rate for fluid appearance, they may be rated by tilting samples on side and observing the material adhering to the beaker.

TABLE 1

CODES FOR RATING COMPATIBILITY OF COMPOUNDED OILS			
Fluid Rating	Sediment Rating	Description	Result of Evaluation
0	-	Absolutely Bright	Pass
1	-	Bright	Pass
2	-	Very Slight Cloudiness	Fail
3	-	Moderate Cloudiness	Fail
4	-	Heavy Cloudiness	Fail
5	-	Detectable Floc	Fail
6	-	Heavy Floc	Fail
-	0	No Sediment	Pass
-	1	Very Slight Sediment	Fail
-	2	Slight Sediment	Fail
-	3	Heavy sediment	Fail
-	4	Appreciable More Sediment Than 3	Fail

### 5.3 TESTING PHYSICAL AND CHEMICAL CHARACTERISTICS OF OIL

Chemical and physical tests shall be conducted in accordance with the Standards listed in TABLE 2.

TABLE 2

#### CHEMICAL AND PHYSICAL CHARACTERISTICS REQUIREMENTS AND TEST METHODS FOR RUST AND OXIDATION (R&O) INHIBITED ISO 68 & 100 TURBINE OILS

Chemical and Physical Characteristics	Requirements		Test Method
	ISO 68 Oil	ISO 100 Oil	
Viscosity at 40 °C, centistokes (cSt)	65-70	95-102	ASTM D 445
Viscosity Index, minimum	98	95	ASTM D 2270
Flash Point, minimum, °C (°F)	204 (400)	210 (410)	ASTM D 92
Pour Point, maximum, °C (°F)	-9 (16)	-9 (16)	ASTM D 97
Acid Number (AN) mg KOH/g, maximum	0.15	0.15	ASTM D 664
Oxidation Stability by Rotating Pressure Vessel Oxidation Test (RPVOT), minutes, minimum	500	500	ASTM D 2272
Oxidation Characteristics, mg KOH/g, maximum	0.5*	0.5*	ASTM D 943
Rust Preventive Characteristics, Procedures "A"	Pass	Pass	ASTM D 665

and "B"			
Water Content, parts per million (ppm), maximum	250	250	ASTM D 6304
Water Separability of Petroleum Oil	40-40-0 (30)	40-40-0 (60)	ASTM D 1401
Corrosion from Oil by Copper Strip Tarnish Test	Classification 1	Classification 1	ASTM D 130
Foaming characteristics  <u>After 5 minutes blowing period:</u> Sequence 1, foam volume in milliliters (ml), maximum Sequence 2, foam volume in ml, maximum Sequence 3, foam volume in ml, maximum  <u>After 10 minutes settling period:</u> Sequence 1, foam volume in ml, maximum Sequence 2, foam volume in ml, maximum Sequence 3, foam volume in ml, maximum	   100 50 100  10 0 10	   100 50 100  10 0 10	ASTM D 892
Air Release Properties, minutes, maximum	30	60	ASTM D 3427
Cleanliness, ISO Code Particle Count, particle sizes of greater than 4, 6, and 14 $\mu\text{m}$ (c)	17/15/12 (c)	17/15/12 (c)	ISO 4406-99 (ISO 11171 Cal.)
Appearance	Clear & Bright	Clear & Bright	Visual Observation

\* At the conclusion of the 1,000 hours test, measured AN should be 0.5 or less. In addition, at that point, the oil and water phases shall be examined for evidence of sludge and catalyst metal corrosion. Permitted maximum level of total sludge in the oil after 1000 hours is 50 mg/kg.

## 6. PRE-DELIVERY TESTING

The Contractor shall test the oil or a sample blend for all chemical and physical characteristics set forth in TABLE 2, and provide the certified test results as well as one gallon sample of the oil to the Government at least thirty days prior to delivery.

The Contractor may conduct compatibility testing of the oil or sample blend. The Government will provide a sample of in-service oils for such purposes on request.

The Government will conduct compatibility testing of the sample, and notify the contractor of the results prior to purchasing of the oil.

## 7. DELIVERY

The Contractor shall deliver the oil according to the delivery requirements specified elsewhere in the contract.



## **8. INSPECTION AND ACCEPTANCE.**

At the point of oil delivery, the Government will obtain samples in a manner specified in ASTM D 4057 or ASTM D 4177, and may perform such tests as are deemed necessary to determine whether the oil meets the specifications values listed in TABLE 2. The delivered oil will remain in a storage tank (if applicable) and will not be used until the test results are received from the laboratory. Should the oil fail any test, the Contractor shall be responsible for disposing of the delivered oil and replacing the oil at its own expense.